ARMY RESEARCH LABORATORY

Looking Back at 20 Years of MANPRINT on Patriot: Observations and Lessons

by John K. Hawley

ARL-SR-0158 **September 2007**

NOTICES

Disclaimers

Army Research Laboratory

Adelphi, MD 20783-1197

ARL-SR-0158 **September 2007**

Looking Back at 20 Years of MANPRINT on Patriot: Observations and Lessons

John K. Hawley
Human Research and Engineering Directorate, ARL

REPORT DOCUMENTATION PAGE			*Form Approved OMB No. 0704-0188*

1. REPORT DATE *(DD-MM-YYYY)*	**2. REPORT TYPE**	**3. DATES COVERED (From - To)**
September 2007		

4. TITLE AND SUBTITLE	**5a. CONTRACT NUMBER**
Looking Back at 20 Years of MANPRINT on Patriot: Observations and Lessons	
	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	**5d. PROJECT NUMBER**
John K. Hawley	
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)	**8. PERFORMING ORGANIZATION REPORT NUMBER**
U.S. Army Research Laboratory ATTN: AMSRD-ARL-HR-ME 2800 Powder Mill Road Adelphi, MD 20783-1197	ARL-SR-0158
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	**10. SPONSOR/MONITOR'S ACRONYM(S)**
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT

Approved for public release; distribution unlimited.

13. SUPPLEMENTARY NOTES

14. ABSTRACT

During the combat operations phase of Operation Iraqi Freedom (OIF), Patriot air and missile defense units were involved in two fratricide incidents. Patriot's unacceptable fratricide rate during OIF (18% of engagements) prompted the commanding general of the Army Air and Missile Defense Center to request a human-performance-oriented assessment of the fratricide incidents to complement the official Army board if inquiry investigation. This report summarizes the results and recommendations from that assessment. Recommendations for a solution to the fratricide problem involved both command and control and training modifications. The paper's primary focus is MANPRINT observations and lessons from the Army's 25-year developmental effort with Patriot. Specific observations on the Patriot MANPRINT program gleaned from a review of assessments and test reports going back 20 years are presented and discussed. This material is followed by a discussion of broader lessons from the Patriot MANPRINT program. These broader lessons include: (1) going-in concepts really matter, (2) training issues really matter, (3) testing must be more comprehensive and rigorous, and (4) lessons must be learned. Implications of the specific observations and broader lessons for the MANPRINT program going forward also are presented and discussed. The observations and lessons discussed in the report are presented in the spirit of action research, defined as research that any community of practice can do to improve its methods. In this sense, the spirit of the report is institutional learning and practice improvement rather than after-the-fact criticism.

15. SUBJECT TERMS

Patriot, training, adaptive expertise, simulation

16. SECURITY CLASSIFICATION OF:			**17. LIMITATION OF ABSTRACT**	**18. NUMBER OF PAGES**	**19a. NAME OF RESPONSIBLE PERSON**
					John K. Hawley
a. REPORT	**b. ABSTRACT**	**c. THIS PAGE**	SAR	28	**19b. TELEPHONE NUMBER** (*Include area code*)
Unclassified	Unclassified	Unclassified			915-568-2896

Standard Form 298 (Rev. 8/98)
Prescribed by ANSI Std. Z39.18

Contents

List of Figures

Introduction

Background

During the combat operations phase of Operation Iraqi Freedom (OIF), Army Patriot units were involved in two fratricide incidents. In the first, a British Tornado was misclassified as an anti-radiation missile (ARM) and subsequently engaged and destroyed. The second fratricide incident involved a Navy F/A-18 that was misclassified as a tactical ballistic missile (TBM) and also engaged and destroyed. Three flight crew members lost their lives in these incidents. OIF involved a total of 11 Patriot engagements by U.S. units. Of these 11, nine resulted in successful TBM engagements; the other two were fratricides.

Patriot is the Army's first-line air and missile defense (AMD) system. The system has been in the active force since the early 1980s. Initially, Patriot was intended as a defense against conventional air-breathing threats (ABTs). However, since Operation Desert Storm (ODS) in the early 1990s, the system has been used primarily against TBMs. Future usage scenarios envision the system being used against a spectrum of air threats including TBMs, conventional ABTs, cruise missiles, and various categories of unmanned aerial vehicles (UAVs). The range of potential air threats in the contemporary operating environment has significantly increased the complexity of the battle command problem for Patriot and other AMD systems.

Since Patriot is an existing system and has been in the Army's inventory since the early 1980s, what do lessons from Patriot tell us about other systems, particularly those at the concept stage or under development? As Patriot has evolved over the past two decades, the system has acquired features and characteristics that are more typical of systems the Army will employ in the future than those in the current inventory. Terms that are now used to describe Patriot include (1) joint, (2) network-centric, (3) complex, and (4) knowledge-intensive. First, command and control (C2) for the Patriot system is joint—involving both the Army and Air Force, and sometimes the Navy. Second, effective employment of system assets is dependent on a robust network. Third, the system as broadly defined is complex in that it consists of a large number of interacting components. And fourth, Patriot is knowledge-intensive in terms of the amount of information required to characterize and comprehend the system. It can be argued that Patriot is a relevant data point regarding human performance issues the Army is likely to face with emerging high technology and network-centric systems. Moreover, this glimpse into the future is tangible and real and not abstract or hypothetical. The lessons discussed in this paper are from the crucible of combat operations and not based solely on the results of operational tests or simulated exercises.

The central focus of the paper is, however, human system integration (HSI) or MANPRINT (Manpower and Personnel Integration) observations and lessons from the Army's 25-year developmental experience with Patriot. [Note: MANPRINT is the Army's HSI initiative. The

program was started several years after Patriot was initially fielded.] This retrospective case study assessment of HSI practices, successes, failures, and lessons was made possible because of a unique research opportunity that resulted from the Patriot fratricides during OIF: The Patriot Vigilance project. The next section provides an overview of the Patriot Vigilance project and its results. Prior to proceeding, it should be noted that the discussion to follow is presented in the spirit of action research, defined as self-directed research that any community of practice can do to improve its methods with the aim of improving its strategies, methods, and knowledge of the environment in which it practices (Schein, 2004). The intent of the report is institutional learning and HSI practice improvement rather than simple after-the-fact criticism.

The Patriot Vigilance Project

Personnel from the Army Research Laboratory's Human Research and Engineering Directorate (ARL HRED) began looking into Patriot and AMD performance and training issues at the invitation of the then Ft. Bliss Commander, Major General (MG) Michael A. Vane. MG Vane was interested in operator vigilance and situational awareness (SA) as they relate to the performance of automated AMD battle command systems. [Note: The generally accepted definition of SA is from Endsley, Bolte, and Jones (2003) who define it as the *perception* of elements in the environment, the *comprehension* of their meaning, and the *projection* of their status in the near future.] MG Vane was particularly concerned by what he termed a "lack of vigilance" on the part of Patriot operators along with an apparent "lack of cognizance" of what was being presented to them on situation displays and a resulting "absolute trust in automation." His request for human factors support was prompted by the unacceptable rate of fratricidal engagements by Patriot units during OIF—two out of a total of 11 engagements, or 18%. MG Vane's reference to lack of vigilance by Patriot operators led to the effort being called the Patriot Vigilance project.

Following general approaches to human error investigations and case study research outlined in Dekker (2002) and Yin (2003), respectively, the project staff spent most of the summer and fall of 2004 performing a human-performance-oriented critical incident assessment of the OIF fratricides. This involved activities such as reading documents from the fratricide boards of inquiry (BOIs), interviewing knowledgeable personnel in the Ft. Bliss area, and observing Patriot training and operations. An initial assessment briefing was delivered to MG Vane in October 2004. The project staff also prepared a supporting technical report describing the human performance problems associated with automation and supervisory control (Hawley, Mares, & Giammanco, 2005).

The logic model (see Yin, 2003) resulting from HRED's critical incident assessment of the OIF fratricides is presented in figure 1. In developing this logic model, the project staff was responding to MG Vane's request to explain "how we got to the OIF incidents." He was not interested in a further dissection of the specifics of the incidents, since those details had been the focus of the various BOIs convened to examine the fratricides. Rather, MG Vane was interested

in understanding how the branch got into a situation in which those incidents were almost inevitable. His observations concerning Patriot operator performance cited above speak directly to the General's view of the situation. The logic model was constructed with this intent in mind. It is explanatory in a broad, conceptual manner rather than in a narrow, technical sense (e.g., a step-by-step dissection of operator actions). HRED's intent also was to point the way to actionable solutions rather than to lay further blame.

The first block in the causal network leading to the OIF fratricides is termed "undisciplined automation," defined as the automation of functions by designers and subsequent implementation by users without due regard for the consequences for human performance (Parasuraman & Riley, 1997). Undisciplined automation tends to define the operators' roles as by-products of the automation. Operators are expected to "take care of" whatever the system cannot handle. However, in the case of Patriot, little explicit attention was paid during design and subsequent testing to determining (1) what these residual functions were, (2) whether operators reasonably could be expected to perform them, (3) how operators should be trained, or (4) the impact on the overall system's (hardware plus operators) decision-making reliability.

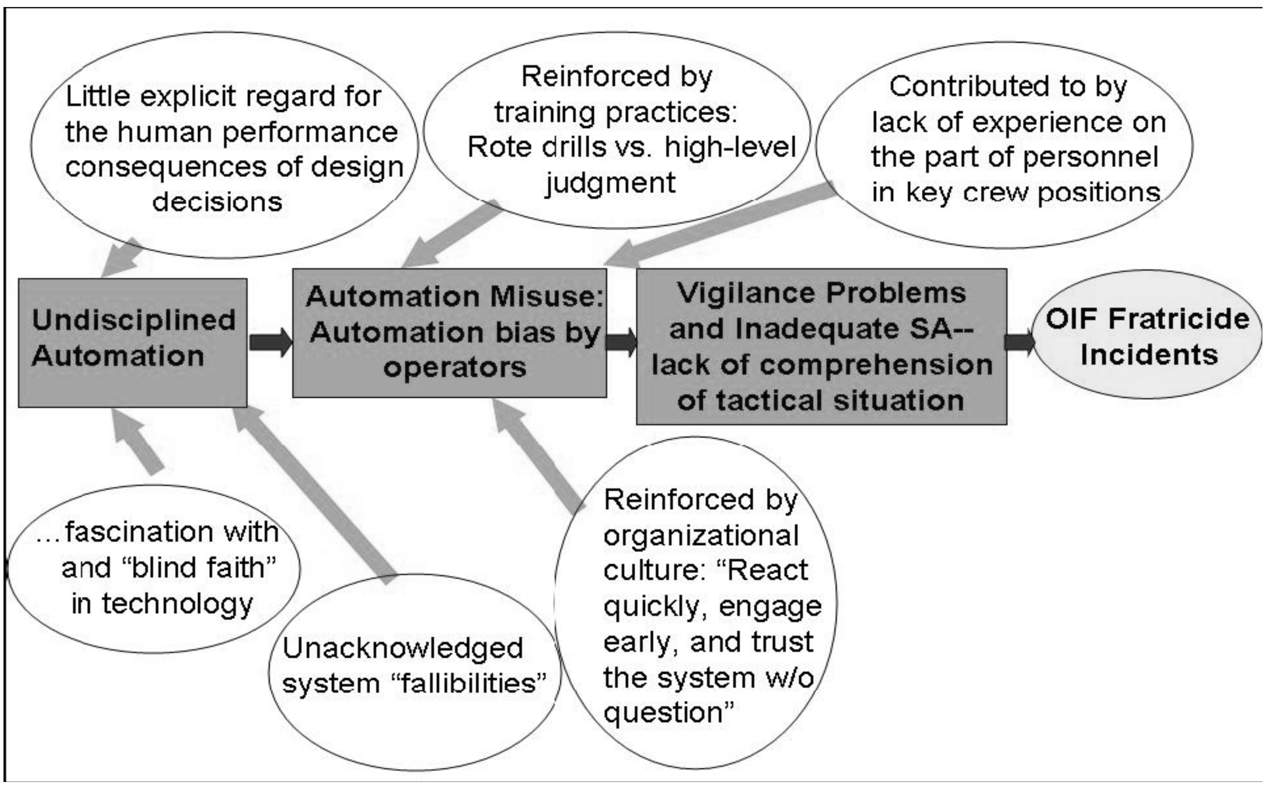

Figure 1. Patriot vigilance logic model.

The downstream impact of undisciplined automation was exacerbated by two additional factors: (1) unacknowledged system fallibilities, and (2) a "fascination with and blind faith in technology." [Note: Several terms presented in quotes without reference citations are taken from the classified BOI reports.] A series of Patriot operational tests indicated that the system's

automated engagement logic was subject to air target (i.e., track) misclassification problems—system fallibilities. However, these sources of automation unreliability were not fully addressed during system software upgrades, nor did information about them find its way into operator training; battle command practices; tactics, techniques, and procedures (TTPs); or Tactical Standing Operating Procedures (TSOPs). System developers continued to pursue technology-centric solutions to automation reliability problems (e.g., increased use of artificial intelligence, non-cooperative target recognition, etc.). But the basic problem remained: The total system (hardware plus crew) was not sufficiently reliable in critical functional areas, most notably track classification and identification. Users were not informed regarding these problems, or if they were informed, little effective responsive action was taken.

In the aftermath of the first Gulf War (ODS), the AMD user community (combat developer, training developer, operational units, etc.) acquiesced to the developmental community's apparent lack of urgency regarding problems with Patriot's track classification accuracy. Emboldened by Patriot's seeming success in engaging the Iraqi SCUD threat during ODS, Patriot's organizational culture emphasized "Reacting quickly, engaging early, and trusting the system without question." Users were allowed to persist in their belief that the system would not confuse air-and non-air-breathing threats such as ARMs and TBMs.

The cultural norm of unwarranted trust in automation was exacerbated by the AMD branch's traditional training practices, which were criticized in BOI reports as emphasizing "rote drills versus the exercise of high-level judgment." The Patriot user community continued to approach training for air battle operations in much the same manner as march order and emplacement or system set-up. The emphasis was on mastering routines rather than active thinking and adaptive problem solving. Klein and Pierce (2001) refer to the result of this practice as "experiosclerosis." Crews believe they are competent and "combat ready" because they are good at the routines, but the routines can prove to be a straitjacket during combat. Traditional individual and unit evaluation practices reinforced this mistaken belief on the part of crews and commanders at all levels by focusing only on satisfactory performance of routine drills. The Army BOI investigating the OIF fratricides stated bluntly that "the system (Patriot) is too lethal to be placed in the hands of crews trained to such a limited standard."

A second detrimental factor was the branch's traditional personnel assignment practices which tended to place inexperienced personnel in key crew positions in the C2 chain: the battery-level Engagement Control Station (ECS) and battalion-level Information and Coordination Central (ICC). Before the first round was fired during OIF, the stage was thus set for what Parasuraman and Riley (1997) refer to as "automation misuse," specifically automation bias on the part of Patriot operators. Automation bias is defined as unwarranted over-reliance on automation, and has been demonstrated to result in failures of monitoring (vigilance problems) and accompanying decision biases (an absolute and unthinking trust in automation—let's do what the machine recommends). Recall that these are the very concerns expressed by MG Vane in his kick-off discussion with the Patriot Vigilance staff.

One must be careful, however, not to lay too much blame for these shortcomings at the feet of the Patriot operators or the supporting battle staff. As suggested in figure 1, the roots of these human shortcomings can be traced back to systemic problems resulting from decisions made years earlier by concept developers, software engineers, procedures developers (government and vendor), trainers, and commanders. In one sense, the OIF Patriot operators did what they had been trained to do and what Patriot's culture emphasized and reinforced. It should also be noted that system developers and users edged into the OIF situation by degrees. As Patriot evolved over its 25-year life, its dominant control mode changed, by degrees, from traditional manual control to supervisory control as increasing levels of automation and other technical features were added to cope with increasingly sophisticated threats and an increasingly complex operating environment.

Hardware-wise, Patriot evolved into a very lethal system. It can be argued, however, that the system was not properly managed during OIF. Driven by technology and mission expansion, the Patriot crew's role changed from traditional operators to supervisory controllers whose primary role is supervision of subordinate automatic control systems. But this role change was not reflected in the AMD culture, design and evaluation practices, battle management concepts, operational procedures, training practices, or personnel usage patterns. Moreover, system management issues (doctrine, battle command concepts, TTPs, TSOPs, etc.) and crewmembers' ability to execute them were not addressed with the same rigor during development and evaluation as hardware and software capabilities. As the lessons of OIF suggest, these aspects of the total "system" are as important to operational effectiveness as hardware and software capabilities.

HRED's briefing to MG Vane in October 2004 described the human performance circumstances that contributed to the fratricides and recommended two primary actionable items to address the problems thus identified:

1. Re-examine automation concepts, operator roles, and C2 relationships in AMD battle command systems to emphasize effective human supervisory control (HSC); and

2. Develop more effective missile crews and C2 teams, or in the words of the Army BOI report "re-look the level of *expertise* required to operate such a lethal system on the modern battlefield."

In present usage, the term effective HSC refers to a situation in which soldiers and not the automated system are the ultimate decision makers in AMD firing decisions. Uncritical acquiescence to the automated system's recommendations is not effective HSC.

A month following HRED's report to MG Vane, the Defense Science Board (DSB) (DSB, 2004) reinforced HRED's conclusions with the following recommendations. Although the full DSB report on Patriot system performance is classified, these extracts are not.

> “The Patriot system should migrate to more of a ‘man-in-the-loop’ philosophy versus a fully automated philosophy—providing operator awareness and control of engagement processes.”

and

> “Patriot training and simulations should be upgraded to support this man-in-the-loop protocol including the ability to train on confusing and complex scenarios that contain unbriefed surprises.”

A summary of the DSB report on Patriot system performance is available for download on the DSB’s web site.

Follow-On Work, Implementation, and Current Status

After reviewing initial project results, the Army Training and Doctrine Command (TRADOC) Capability Manager for Lower Tier AMD systems (TCM-LT), requested that the Patriot Vigilance project continue into a second phase. The TCM specifically requested that HRED’s project staff expand on the material presented in Hawley, Mares, and Giammanco (2005) and prepare two, more-detailed reports, one concerned with design for effective human supervisory control and a second addressing training for the emerging class of automated AMD battle command systems. In the TCM’s words, the intent of these reports was to inform the AMD community on “what right looks like” in each of these topic areas. The results of the second phase of the effort were the technical reports *Developing Effective Human Supervisory Control for Air and Missile Defense Systems* (Hawley & Mares, 2006) and *Training for Effective Human Supervisory Control of Air and Missile Defense Systems* (Hawley, Mares, & Giammanco, 2006). Both reports contain a summary and discussion of the technical state of the art in each of the topic areas. In addition, supporting informational briefings were developed for use across the AMD community. The project staff also worked with various elements in the AMD system development (combat and materiel developer), training, and user communities on operationally defining and implementing Patriot Vigilance recommendations. Phase two formed the theoretical basis for what later were to be turned into actual design and training modifications.

In the late summer of 2005 after MG Vane had left Ft. Bliss for another assignment, the project staff briefed his replacement, MG (then Brigadier General) Robert P. Lennox, on the status and results of the Patriot Vigilance project. Based on this presentation and subsequent urging from the TCM-LT, MG Lennox formally requested that the project be continued for at least another year so that the technical staff could continue to work with the AMD community on implementing selected results. HRED’s project staff also would participate as the MANPRINT evaluator during an operational test of the Post-Deployment Build 6 (PDB-6) software suite for the Patriot system. PDB-6 was developed to address many of the Patriot system’s operational deficiencies that had surfaced during OIF and were generally considered to have contributed to the unacceptable fratricide rate.

It also turned out that in addition to wide-ranging software fixes, the PDB-6 operational test was expanded to address a number of changes consistent with HRED's first actionable item concerning a re-examination of automation concepts, operator roles, and C2 relationships in AMD battle command systems to emphasize effective HSC. The centerpiece of these changes was the integration of a Fire Coordination Center (FCC) into the Patriot battalion command post. The FCC represents an enhanced C2 entity similar in concept to the combat information center on Navy Aegis cruisers. If the FCC concept proved successful, it rather than the traditional ECS-ICC combination would become the "trigger-puller" for Patriot units. With the introduction of the FCC, the branch was implicitly recognizing that "two people inside a van (the ECS) conducting engagement operations is no longer viable." The FCC potentially represents a significant step forward in addressing the SA problem that contributed to the C2 failures of OIF. First, however, it would have to be demonstrated (1) that the FCC provided the incremental SA essential for more accurate engagement decision making and (2) that the new C2 configuration could do so in a timely manner. Engagement decision time lines for Patriot against TBMs are very short—less than 10 seconds in the case of the fratricide involving the British Tornado during OIF. Decision cycle time is a significant issue in AMD battle command.

From the fall of 2005 through the summer of 2006 during the New Equipment Training (NET) and unit train-up period for the PDB-6 test, the HRED project staff's observations regarding the progress of training for the test unit sounded an alarm. PDB-6 training was not progressing according to plan. Training events were being completed, but individual and crew performance objectives were not being met. In addition, many of the training issues identified and discussed in Hawley, Mares, and Giammanco (2006) were re-surfacing and were not being addressed adequately by the NET process or follow-on collective training by the test unit. These included but were not limited to (1) an emphasis on training events to the exclusion of test player performance capabilities, (2) lack of focus on the unit's core test mission—air battle operations, (3) inadequate standards, (4) inappropriate training methods, and (5) inadequate performance feedback—the after-action review (AAR) process.

The project staff viewed these deficiencies as a serious problem because inadequate test player training would compromise the validity of test results and undermine the basis for evaluating the value added of PDB-6 software changes, the FCC concept, and other C2 modifications (see Hawley, 2007a). Even more serious was the fact that fratricides and fratricide-inducing conditions (e.g., dropped or improperly correlated tracks, loss of network connectivity, etc.) similar to those that occurred during OIF were still all-too-frequent during the test itself. Many of the human performance problems that had shown up during OIF were apparent again, with similar results.

The Patriot and AMD C2 situation is not all gloom and doom. As a result of the Patriot Vigilance project and HRED's participation in the PDB-6 LUT, beneficial changes are in the offing. These include (1) new concepts for effective HSC for Patriot and follow-on AMD systems (e.g., the FCC and a follow-on AMD integrated battle command system); (2)

performance-oriented concepts for NET and unit train-up prior to testing for Patriot enhancements (e.g., PDB-6.5 and -7.0); (3) modified concept evaluation and test and evaluation practices; and (4) a revision of institutional and unit training practices to emphasize deliberate practice, active thinking, and sensemaking over traditional crew drills. An overview of these developments is provided in Hawley (2007b).

MANPRINT Observations and Broader Lessons

The idea for a MANPRINT observations and lessons assessment using Patriot as an exemplar grew out of a conversation with the TCM-LT prior to the conclusion of the PDB-6 LUT. After discussing emerging results from the test and recommendations from the Patriot Vigilance project, the TCM said something to the effect that "We've been doing MANPRINT work on Patriot for more than 20 years. How did we miss all of the things you wrote about and that we're now seeing? Certainly all of these things are not new." These questions prompted the project staff to ask the obvious follow-on questions "How did we miss these high-driver issues? Or, did we note these things and nothing came of them?" These latter questions led to a review of the available Patriot-related MANPRINT assessments and test reports going back to the start of the formal MANPRINT initiative in the mid-1980s. Prior to MANPRINT's formalization in 1985, human factors concepts were different. HSI as we understand the term today was not explicitly a goal in system development. Rather, the concern in those days was a rather narrow view of what is now termed human factors engineering (HFE): Properly engineering the interface between users and the hardware system, or fitting the person to the system.

The next section presents the project team's observations concerning the Patriot MANPRINT program that evolved after 1985. Readers should note that the operant word in the previous sentence is "evolved." MANPRINT concepts as applied to Patriot evolved from a nearly strict preoccupation with HFE to include a broader concern for other nominal MANPRINT domains: Manpower, Personnel, Training, System Safety, Health Hazards, and Soldier Survivability. The project staff has tried to avoid hindsight bias and judging earlier MANPRINT activities by the conceptual standards of today. Again, the intent is practice improvement rather than mere criticism of what went on with Patriot.

Observations on Patriot MANPRINT

A review of MANPRINT documents and test reports going back to the mid- to late-1980s and into the 1990s indicated that the term evolved might actually be a misnomer when describing the Patriot MANPRINT program. Early assessments focused on what might be termed "1472 issues" (control and display features, symbology concerns, etc.) and user-jury type evaluations. The term 1472 issues refer to the concerns addressed in MIL-STD-1472, Human Engineering.

User-jury type assessments refer to the extensive use of questionnaires and interviews during system evaluation. User-jury data typically are collected from a panel of recognized experts.

There is nothing inherently wrong with the assessment methods alluded to in the previous paragraph. They are a part but not all of most contemporary MANPRINT assessments. Problems began to arise, however, when our MANPRINT methods did not evolve as the system evolved. Over the course of its 25-year life, Patriot evolved from a system that was quite literally just one-step more advanced than its predecessor, the Hawk missile system, to the complex system that exists today. As more and more technology and software capability was added to the Patriot system, the operators' roles changed from traditional manual control to supervisory control, bringing with it everything that goes with that control mode. Our MANPRINT methods did not advance in concert with system enhancements. We continued to look at the system as if it were no different than a traditional manual system. The MANPRINT assessments performed for later system upgrades were not substantially different from those performed early in the system's development. Moreover, many of the human performance problems that became apparent during OIF and later during the PDB-6 LUT were starting to show up in earlier test results. But the MANPRINT community did not raise a red flag, and potential show-stoppers either were ignored or allowed to be downplayed. The most common form of downplaying was to dismiss human performance problems as isolated training issues that could be fixed later during institutional or unit training. It should be noted that most of the human performance problems thus identified and categorized as training problems were never actually addressed.

The bottom line with respect to the 20-year history of Patriot's MANPRINT program is that we as a community missed the elephants in the middle of the room. These were (1) an eroding potential for effective human supervisory control, and (2) the need for increased levels of operator expertise—not simply additional training of the traditional kind, but training with a focus on developing operator expertise. It should be noted that the DSB's post-OIF review of Patriot system performance focused quickly on these issues, as did the Patriot Vigilance assessment requested by MG Vane. Furthermore, similar problems were apparent in related domains going back to near the time the Patriot system was initially fielded. These domains include nuclear power operations and the 1979 Three Mile Island incident; Navy anti-air operations and the 1988 USS Vincennes-Iranian airbus incident; and the FAA's $3.5 billion Advanced Automation System (AAS) "meltdown" in the 1990s. [See Bar-Yam (1997) for a discussion of the events leading to the "safety veto" of the AAS.] All of these incidents were reported and discussed widely in the human factors literature, yet no mention of them is found in Patriot MANPRINT documents—despite the fact that Patriot's operational concept has many features in common with these systems.

In all fairness, the MANPRINT community was not alone in failing to emphasize the potentially serious impact of the control and training problems on Patriot system performance. We are part of a team, and the other members of the system development team—the system's prime

contractor, the materiel developer, the combat developer, the TCM, and the Army test and evaluation (T&E) community—all overlooked or downplayed these issues. These observations regarding Patriot mostly would be moot were it not for the fact that this insensitivity to the downside potential associated with human performance issues continues to be prevalent. It was observed during the Patriot Vigilance project; it was apparent during the PDB-6 LUT and its aftermath; and it continues to be a problem in AMD systems other than Patriot. The natural tendency of most of the other players is to downplay human performance issues as isolated incidents or as inconvenient, troublesome problems with no clean (i.e., technology-oriented) solution.

In the case of Patriot with PDB-6, a strong case was made regarding the potential seriousness of the control and training issues. Based on these conclusions and supporting material, headway toward developing and implementing a training fix also was made in the Air Defense Artillery (ADA) School (see Hawley, Mares, Fallin, & Wallet, 2007). However, the request for a PDB-6 conditional materiel release contained the usual "all is well with the system" comments and mostly ignored the human performance problems and training inadequacies that showed up clearly in test results and were similar to those that were judged by the Army BOI to have contributed to the Patriot fratricides during OIF.

Broader Lessons from Patriot

Beyond the specific observations stemming from our review of Patriot MANPRINT materials going back some 20 years, there are a series of lessons from the Patriot experience that generalize to present and future system development efforts other than Patriot. Several of the more prominent of these broader lessons from Patriot are now briefly discussed.

Going-In Concepts Really Matter. The first general lesson to be taken away from the Patriot MANPRINT experience is that going-in concepts really matter. If a flawed system concept is allowed to proceed into development, it may prove impossible to modify that concept later to obtain necessary levels of performance. Faulty going-in concepts pursued into development can create a cul-de-sac from which there might not be a graceful exit. A good example of this situation is the safety veto of the FAA's AAS for air traffic control in the late 1990s after more than $3.5 billion had been spent on its development. Judging from available documentation on the system's demise, it was undone by a combination of controller reluctance to accept the system coupled with operational test results suggesting that the system might not be reliable enough to deploy as an operational air traffic control system (Bar-Yam, 1997).

In the case of Patriot, the system's going-in concept flew in the face of several well-known (even for that time) dilemmas concerning automated systems. The first of these has been termed the brittleness problem of automata (Woods, 2002). The brittleness dilemma refers to breakdowns in handling atypical or off-nominal situations—similar to those that occurred during OIF. Patriot's developers disregarded the brittleness issue and proceeded under the assumption that automation would eliminate many of the human performance problems associated with earlier

AMD systems and also reduce training requirements. Both assumptions proved to be unfounded. As noted previously, automation applied to real-time C2 changes the operators' roles from traditional operators to supervisory controllers. And that subtle role shift brings with it what has been termed the Catch-22 of human supervisory control (Reason, 1990). Consequently, Patriot finds itself in somewhat the same situation as the FAA's AAS. The system's developers have committed to a system concept that demonstrates patterns of performance unreliability that might prove difficult and expensive to correct. More attention to proper operator-system function allocation and the potential downside of automation as the system evolved might have resulted in a product that exhibited fewer of these problems.

Training Issues Really Matter. The second general lesson emerging from the Patriot MANPRINT experience is that training issues really matter. As noted previously, while the Patriot system evolved over its 25-year life, system enhancements (new hardware features, new software drops like PDB-6, etc.) the system became more complex. Increased complexity coupled with the operator role shift from traditional operator to supervisory controller added to the system's training burden. Yet this increase in training requirements was not matched by corresponding changes in institutional or unit training. Hawley, Mares, and Giammanco (2006) and Hawley and Mares (2007) argue that changes in system complexity must drive quantitative and qualitative changes in the associated training program. Training must more rigorous and qualitatively different in the sense that it emphasizes the development of mental models and knowledge structures and not simple habit transfer, what the Army BOI referred to as "rote drills." This view is supported by other observers such as the Defense Science Board. In the first of two reports on training for future conflicts, the DSB (2001) cautioned that an increasing risk exists that training failures will negate hardware promise. Their 2003 follow-on report further remarked that the future will require that more of our people do new and more complicated things, and "meeting this challenge amounts to a qualitative change in the demands placed on our people that cannot be supported by traditional training practices" (DSB, 2003, p. 38).

These observations regarding the human performance impact of system complexity are not particularly new or unique to AMD. For example, in her classic work *In the Age of the Smart Machine*, Shoshanna Zuboff (1988) remarks that computer-mediated work like that found in many new systems brings with it an increase in "intellective skill requirements." Commenting on what they had observed during Operation Desert Storm in the early 1990s, Cordesman and Wagner (1996, p. 25) note that technical advances are used to demand more from operators, and meeting these demands often requires "exceptional human expertise." More recently, an early operational assessment of DARPA's Command Post of the Future (CPOF) currently being used by the Army in Iraq remarks that in order to take advantage of the features provided by this new capability there is a "need for a soldier with a wider 'intellectual bandwidth,' where management and assimilation of information from many sources is a necessity" (Center for Army Lessons Learned, 2005, p. vii). In a case study assessment of the impact of net-centric operations using the Stryker Brigade Combat Team (BCT) as an exemplar, Gonzales, Johnson, McEver, Leedom,

Kingston, and Tseng (2005, p. 35) concluded that “training is more important than ever in the Stryker brigade and other digitized units because the networking and battle command systems employed are more complex than those used in analog-equipped brigades. If soldiers and commanders are not adequately trained on the NCW [network-centric warfare] systems and are not proficient in their use in stressful battlefield conditions, then these NCW systems can be a hindrance rather than a help in combat.” Finally, in a post-test briefing to the Vice Chief of Staff of the Army concerning the Army Battle Command and Enablers (ABCE) system of systems, the Army Test and Evaluation Command (ATEC) concluded “There is no indication that units can dedicate the time, resources, or personnel to adequately train on the digital C4I systems and allow the unit to adequately comprehend the system’s capabilities, much less exploit these systems as a force multiplier” (ATEC, 2006).

So what does all of this have to do with MANPRINT? The answer is captured in the two DSB comments cited above. First, risk exists that training failures will negate hardware promise, and second, the notion that new systems may impose a training burden that cannot be supported by traditional training practices. When viewed from these perspectives, training issues are indeed a system development problem. For example, in the case of Patriot with PDB-6, the Army Evaluation Center’s System Assessment Report concluded that operator performance requirements for PDB-6 exceeded the current Army training standard. This conclusion is significant with respect to downstream system performance. The implication is that if training practices remain unchanged, the Patriot system with PDB-6 has become too complex for its operators to employ effectively. The DSB’s warning that training failure might negate hardware promise will have become a reality.

MANPRINT analysts and assessors must forcefully advocate quantitative and qualitative training changes when assessment or test results support a conclusion like that put forward above for ABCE or that emerging from the PDB-6 LUT. The operational demonstration of new training capabilities and methods for AMD unit training reported in Hawley, Mares, Fallin, and Wallet (2007) provides an example of the kinds of positive change that can result from effective advocacy by the MANPRINT community. Admittedly, the AMD operational demonstration is a tentative first step in the direction of implementing the changes that will be necessary to bring AMD unit training into line with system requirements, but it is a first step.

Testing Must be More Comprehensive and Rigorous. The third general observation emerging from the review of MANPRINT practices with the Patriot system is that operational testing must be more comprehensive and rigorous, particularly where the impact of human performance on system performance is concerned. During the PDB-6 LUT, for example, the MANPRINT support team encountered a strong bias on the part of testers to look at the system primarily from a hardware and software perspective. The impact of operator performance on system performance was regarded as a secondary issue—one that could be taken care of mostly with user-jury type questionnaires. User-jury type questionnaires are potentially useful in system evaluation, but they should not be the sole source of data regarding the operators’ impact on

system performance. Operators who are not familiar with new system functions and requirements often “don’t know what they don’t know,” thus their subjective assessments may lack critical information regarding the system’s performance potential.

Looking back on the situation with the PDB-6 LUT and other tests, the fact that MANPRINT (i.e., Soldier performance) is classified as a supportability issue and not a system performance issue during test design and conduct undoubtedly contributes to the hardware-software bias noted above. Dekker (2002) argues that complex systems like Patriot and others coming into the Army inventory require an “overwhelming human contribution” for their effective operation. He goes on to state that “people are the only ones who can hold together the patchwork of technologies in their world; the only ones who can make it work in actual practice” (p. 103). Given this view backed up with the observations reported in the previous subsection, it is hard to justify the notion that Soldier performance is a secondary issue during T&E. Soldier impact on system performance cannot continue to be viewed as a secondary issue. Continuing to do so opens the door to total system reliability problems like those that contributed to the Patriot fratricides during OIF. For Patriot, it was assumed that operators would be able to compensate for known hardware-software reliability problems in the area of track classification accuracy, but this assumption was never verified empirically during testing. Later events during OIF indicated that the assumption was unwarranted.

Meaningfully putting the human component into the testing equation for human-machine systems will require a significant change in the way the Army prepares test players to participate in operational tests (see Hawley, 2007a). In present usage, the term “test players” refers to the individuals, crews, or units participating in a test event. Both the Defense Science Board and the Government Accountability Office (GAO) have criticized the Department of Defense in general, and the Army in particular, for not properly preparing test players to participate in operational tests (e.g., DSB, 1999, 2003; GAO, 2000). The DSB has stated bluntly that the “Army continues to field new equipment without adequate training” (DSB, 2003, p. 44). Training deficiencies for new systems are a problem for receiving organizations, but they can be remedied with use over time. However, for T&E, pre-test training deficiencies can have more serious consequences—because T&E frequently is a one-shot affair. The GAO notes that testing is the primary means used to gauge the progress being made when a concept is translated into an actual product for users; it is the basis for determining fitness for use before the product is provided to users (GAO, 2000).

Failures in the training domain would not be particularly of interest to testers were it not for the serious downstream impact of inadequate training on test integrity. The GAO and DSB both caution, for example, that inadequate training of test participants seriously undermines the validity of test results. Following a review of a representative sample of operational tests, Hawley and Frederickson (1990) concluded that inadequate test player preparation was one of the most frequent reasons for test failure. Failure, in present usage, refers to an inability to cleanly address test issues using test data. These authors cautioned that if test player capabilities

are uncertain, test results are likely to be compromised. The most common form of compromise is confounding between test outcomes and pre-test proficiency levels. It is not possible to state unambiguously that test outcomes reflect system capabilities and features, test player proficiency, or some combination of the two.

In GAO's terminology, poor test player preparation almost inevitably results in a "hollow test" (GAO, 2000, p. 5). A hollow test is one that satisfies the requirement to hold a testing event, but does not advance system-related knowledge. Consequently, test results provide little insight into the system's performance potential and cannot be used to debug or improve the system. Test planners often attempt to compensate for an emerging hollow test by restricting or scripting test events as a workaround for test player performance deficiencies. A great deal of this "re-scripting" was observed during the PDB-6 LUT. But such tactics do not really address the faulty train-up issue. Regardless of the camouflage used, the test is still hollow. Clever statistics and sophisticated post-test analyses cannot compensate for an intrinsically flawed test. For test results to be meaningful, test planners must verify that test players have been trained to the competency levels required by test events.

Lessons Must be Learned. Former Chief of Staff of the Army, General Eric Shinseki, is credited with the observation that lessons are not learned until a resulting change occurs. If change does not occur, the lessons are merely "observed." The same might be said of MANPRINT lessons and results. In the case of Patriot and PDB-6, the MANPRINT team encountered enormous pressure to pass the system on and support a conditional materiel release for PDB-6 with the promise that problems emerging from the test would be fixed later. This occurred in spite of the fact that similar problems showing up in earlier tests or as lessons from combat operations during OIF had not yet been acted upon. Hard and unpleasant facts must be faced and acted upon explicitly. In the absence of action, problems typically do not get better with time; and ignoring problems does not make them go away.

One interesting observation emerging from the PDB-6 test concerns the handling of feedback from operational tests, specifically feedback concerning training, doctrine, or procedural inadequacies impacting overall system performance. Materiel developers (e.g., Program Managers) routinely get feedback from T&E and are accustomed to addressing system inadequacies based on test results. These "wickets" in the system development process are routinely used and well developed. Resource or other constraints may prevent the timely implementation of essential materiel fixes, but the mechanism for their acknowledgement is well known.

Such is not the case for training, doctrine, or procedural inadequacies—the stuff of many MANPRINT assessments. In the case of training, for example, feedback regarding training inadequacies such as those found in the PDB-6 LUT would have to go to TRADOC for institutional training fixes and to various Major Commands (e.g., Forces Command—FORSCOM) for unit training modifications. The Army Independent Evaluator judged that it had

no authority to task TRADOC or FORSCOM for any mitigation plan addressing training fixes. These commands could be apprised of potential training problems, but no formal acknowledgement of the problem or plan for its remedy is required in response. (Apparently, only the Army G3 has the authority to task the MACOMS.) As noted, such is not the case with respect to materiel deficiencies. PMs are routinely required to provide so-called “get well” plans in response to system deficiencies (per AR 700-142). The get well plan is a condition for materiel release, and the progress of its implementation is monitored by the Independent Evaluator. There is an old adage that what gets measured gets done. Until doctrine, tactics, procedures, training methods, training support (training devices), and other parts of the total system package (e.g., the DOTLM-PF components, minus the M) are put on the same plane as materiel, only part of the feedback from T&E has any potential for long-term beneficial impact.

MANPRINT Going Forward

The previous section noted that one of the primary motivators for this report was the TCM-LT’s musing concerning how during 20 years of MANPRINT work on Patriot we missed many of the human performance and training problems that contributed to the fratricides during OIF. It cannot be stated with any certainty that the issues of effective human supervisory control and inadequate training were completely missed. However, it is certain based on the review of available MANPRINT assessments and test reports that a discussion of these issues never made it into those documents. Hence, in that sense, the issues were missed. In retrospect, one must conclude that the TCM’s implied criticism of the Patriot MANPRINT program was justified.

This conclusion raises the broader question of why these issues were missed. Part of the answer lies in the previous observation that our MANPRINT methods did not evolve along with the system. An eroding potential for effective HSC and the concomitant problem of inadequate training came in on the coattails, so to speak, of technical enhancements to the Patriot system over time. However, we kept doing what we had always done, but that something became increasingly inadequate. A contributor to this problem lies in the way the MANPRINT program was set up originally. Back in the 1985-86 timeframe when the program was codified in AR 602-2, the breakout of the MANPRINT program into semi-independent domains—HFE, Manpower, Personnel, Training, Soldier Survivability, Health Hazards, and Soldier Survivability—preserved the stakeholder “rice bowls” that existed at that time. However, the all-important issue of domain integration was mostly given lip service. Platitudes concerning the importance of domain integration were put into the Regulation and supporting documents, but no mechanism was put in place to bring it about. The lesson from Patriot is that MANPRINT domain integration involves more than a simple concatenation of assessments from the component domains. An effective MANPRINT program is more than simple the sum of its

domain parts. In Patriot, operator performance issues that emerged at the intersection of domains such as automation, supervisory control, and their impact on operator performance demands and training requirements simply fell through the cracks.

A second observation regarding MANPRINT going forward is the need for a broader analytical and programmatic perspective. As a combined work program, the Patriot Vigilance project, the PDB-6 LUT, and subsequent efforts at implementation such as the training operational demonstration, support and illustrate this view. Vicente (2006) and others advocate what might be termed a sociotechnical systems (STS) approach to MANPRINT and HSI. An STS approach to MANPRINT begins with the premise that people (the social part of the system) and technology must be viewed as an integrated system, and that both the social and technical parts of the system must be optimized equally and as a unit. Nothing of this sort happened with Patriot as it evolved, and nothing of the sort is happening with follow-on AMD systems. In spite of General Max Thurman's admonitions about the dangers of manning systems versus equipping people and organizations to accomplish a mission, we still mostly build systems and then put people into them—and then put those systems into existing organizations. (Max Thurman is generally considered to be the "Godfather" of the Army's MANPRINT initiative.) It should be noted that the structure of the Army's system development process almost guarantees that things will work this way.

Vicente's (2006) notion of what comprises an STS approach to MANPRINT and system development is shown in figure 2. All of the steps on the sociotechnical ladder are necessary for the initiative to succeed and contribute to system and organizational effectiveness. Based on the Patriot experience, figure 2 also suggests that issues become more problematic as one ascends the ladder, but all the steps are necessary—all the way to the top. In the case of Patriot, for example, the project staff is discovering that issues on the top two steps—Organization and Political—seriously impact solutions to issues at lower levels. Implementing the training fixes indicated by the OIF BOIs, the Patriot Vigilance project, and follow-on work is impeded by Patriot and AMD's organizational culture (the way we routinely do things) and political issues (e.g., TRADOC and MACOM policies, budgetary pots, regulations at various levels, stakeholder rice bowls, etc.). As MANPRINT practitioners, we cannot change culture or affect politics directly, but we must apprise decision makers of the potential impact of these factors on system and organizational effectiveness.

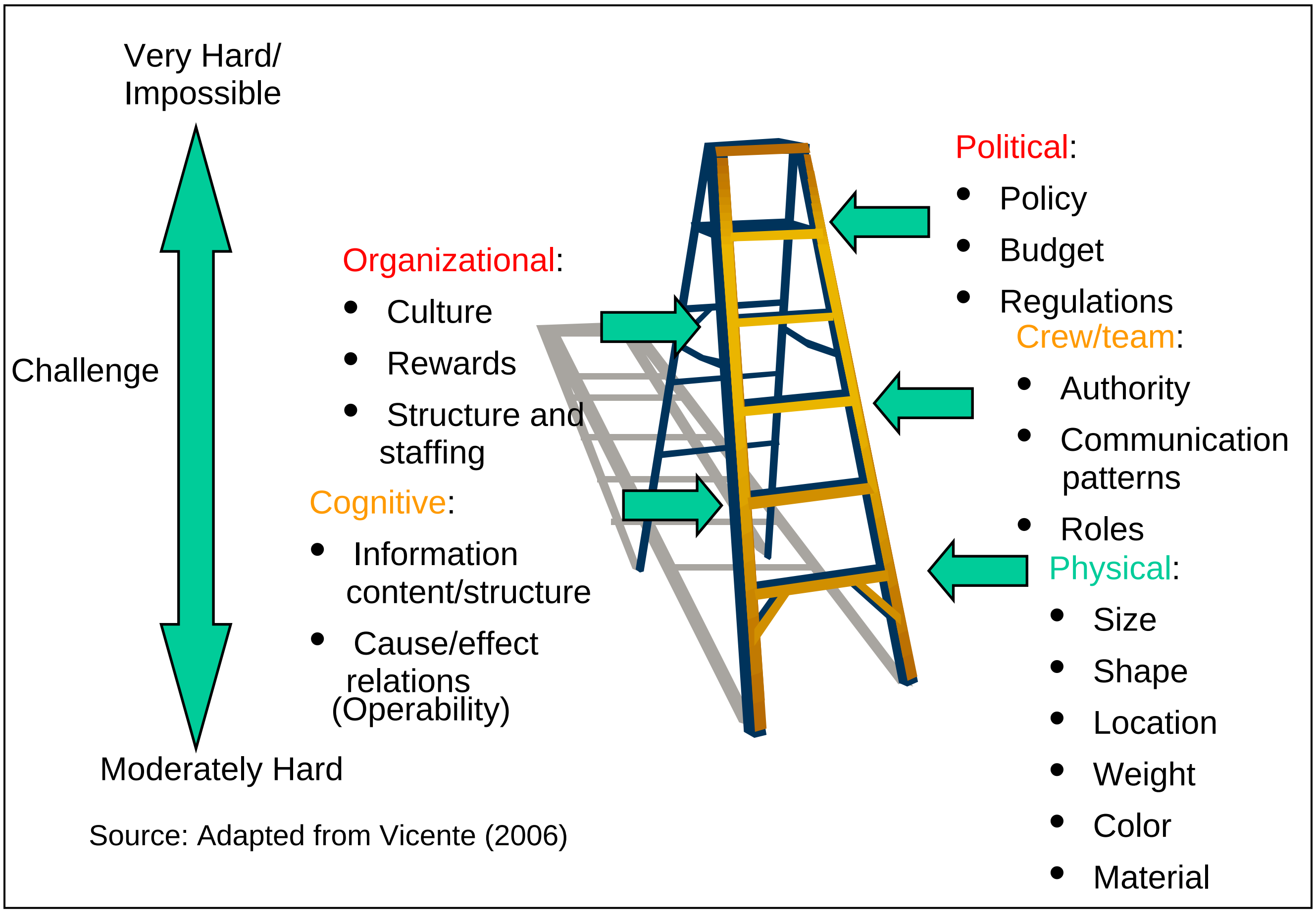

Figure 2. Ladder of sociotechnical concerns.

References

Army Test and Evaluation Command. [Army Battle Command and Enablers]. Unpublished test summary briefing, 2006.

Bar-Yam, Y. *Dynamics of complex systems*; Reading, MA: Perseus, 1997.

Center for Army Lessons Learned. *Command post of the future (CPOF) early operational assessment* (Initial Impressions Report 05-21). Ft. Leavenworth, KS: TRADOC System Manager – Battle Command, 2005.

Cordesman, A. H.; Wagner, A. R. *The lessons of modern war—Vol.4: The gulf war*; Boulder, CO: Westview Press, 1996.

Defense Science Board. *Test and evaluation*. (Final Report of the DSB Task Force on Test and Evaluation). Washington, DC: Office of the Undersecretary of Defense for Acquisition, Technology, and Logistics, 1999.

Defense Science Board. *Training superiority and training surprise*. (Final Report of the DSB Task Force on Training Superiority and Training Surprise). Washington, DC: Office of the Undersecretary of Defense for Acquisition, Technology, and Logistics, 2001.

Defense Science Board. *Training for future conflicts*. (Final Report of the DSB Task Force on Training for Future Conflicts). Washington, DC: Office of the Undersecretary of Defense for Acquisition, Technology, and Logistics, 2003.

Defense Science Board. *Patriot system performance*. (Final Report of the DSB Task Force on Patriot System Performance). Washington, DC: Office of the Undersecretary of Defense for Acquisition, Technology, and Logistics, 2004.

Dekker, S. *The field guide to human error investigations*; Burlington, VT: Ashgate, 2002.

Endsley, M. R.; Bolte, B.; Jones, D. G. *Designing for situation awareness: An approach to user-centered design*; New York: Taylor & Francis, 2003.

Government Accountability Office. *Best practices: A more constructive test approach is key to better weapon system outcomes;* (GAO/NSAID-00-199); Washington, DC: U.S. Government Accountability Office, 2000.

Hawley, J. K. Training and testing: A complex and uneasy relationship. *ITEA Journal of Test and Evaluation* **2007a**, *27* (4), 34-40, December 2006/January 2007.

Hawley, J. K. *Patriot after Operation Iraqi Freedom: A case study in constructive change*; Draft ARL Special Report; U.S. Army Research Laboratory: Adelphi, MD, 2007b.

Hawley, J. K.; Frederickson, E.W. *MANPRINT guidelines for soldier performance evaluation in early user test and experimentation*. Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences, 1990.

Hawley, J. K.; Mares, A. L. *Developing effective human supervisory control for air and missile defense systems*; ARL TR 3742; U.S. Army Research Laboratory: Adelphi, MD, 2006.

Hawley, J. K.; Mares, A. L. *Developing effective adaptive missile crews and command and control teams for air and missile defense systems*; ARL SR 149; U.S. Army Research Laboratory: Adelphi, MD, 2007.

Hawley, J. K.; Mares, A. L.; Fallin, J. I.; Wallet, C. *Reconfigurable tactical operations simulator (RTOS) operational demonstration in 5-52 air defense artillery*; Draft ARL SR; U.S. Army Research Laboratory: Adelphi, MD, 2007.

Hawley, J. K.; Mares, A. L.; Giammanco, C. A. *The human side of automation: Lessons for air defense command and control*; ARL TR 3468; U.S. Army Research Laboratory: Adelphi, MD, 2005.

Hawley, J. K.; Mares, A. L.; Giammanco, C. A. *Training for effective human supervisory control of air and missile defense systems*; ARL TR 3765; U.S. Army Research Laboratory: Adelphi, MD, 2006.

Klein, G.; Pierce, L. Adaptive teams. In *Proceedings of the 6th International Command and Control Research and Technology Symposium*, Annapolis, MD, 2001.

Parasuraman, R.; Riley, V. Humans and automation: Use, misuse, disuse, abuse. *Human Factors* **1997**, *39* (2), 230-252.

Reason, J. *Human error*; Cambridge: Cambridge University Press, 1990.

Schein, E. H. *Organizational culture and leadership*; San Francisco: Jossey-Bass, 2004.

Vicente, K. *The human factor: Revolutionizing the way people live with technology*; New York: Routledge, 2006.

Woods, D. D. Steering the reverberations of technology change on fields of practice: Laws that govern cognitive work. *Proceedings of the 24th Annual Meeting of the Cognitive Science Society (Plenary Session)*, 2002.

Yin, R. K. *Case study research: Design and methods* (Third Edition); Thousand Oaks, CA: Sage, 2003.

Zuboff, S. *In the age of the smart machine: The future of work and power*; New York: Basic Books, 1988.

Distribution List

ADMNSTR
DEFNS TECHL INFO CTR
ATTN DTIC-OCP (ELECTRONIC COPY)
8725 JOHN J KINGMAN RD STE 0944
FT BELVOIR VA 22060-6218

DARPA
ATTN IXO S WELBY
3701 N FAIRFAX DR
ARLINGTON VA 22203-1714

OFC OF THE SECY OF DEFNS
ATTN ODDRE (R&AT)
THE PENTAGON
WASHINGTON DC 20301-3080

ARL HRED AMEDD FLD ELMT
ATTN AMSRD-ARL-HR-MM V RICE-BERG
BLDG 4011 RM 217 1750 GREELEY RD
FT SAM HOUSTON TX 78234-5094

ARL-HRED AMCOM FLD ELMT
ATTN AMSRD-ARL-HR-MO J MINNINGER
BLDG 5400 RM C-242
REDSTONE ARSENAL AL 35898-7290

US ARMY RSRCH DEV AND ENGRG CMND
ARMAMENT RSRCH DEV AND ENGRG CTR
ARMAMENT ENGRG AND TECHNLGY CTR
ATTN AMSRD-AAR-AEF-T J MATTS
BLDG 305
ABERDEEN PROVING GROUND MD 21005-5001

ARMY G1
ATTN DAPE-MR B KNAPP
ARMY G1 MANPRINT DAPE MR
300 ARMY PENTAGON RM 2C489
WASHINGTON DC 20310-0300

ARMY RSCH LAB-HRED JFCOM JOINT
EXPERIMENTSATION J9 JOINT FUTURES LAB
ATTN AMSRD-ARL-HR-MJK J HANSBERGER
115 LAKEVIEW PARKWAY STE B
SUFFOLK VA 23435

ARMY RSRCH LAB-HRED
ATTN AMSRD-ARL-HR-MU M SINGAPORE
6501 E 11 MILE RD MS 284 BLDG 200A 2ND FL
RM 2104
WARREN MI 48397-5000

ARMY RSRCH LABORATORY-HRED
ATTN AMSRD-ARL-HR-MQ M R FLETCHER
AMSRD-NSC-WS-E BLDG 3 RM 343
NATICK MA 01760-5020

ARMY RSRCH LABORATORY-HRED
ATTN AMSRD-ARL-HR-ML J MARTIN
MYER CENTER RM 2D311
FT MONMOUTH NJ 07703-5601

ARMY RSRCH LABORATORY-HRED
ATTN AMSRD-ARL-HR-MG R SPINE
BUILDING 333
PICATINNY ARSENAL NJ 07806-5000

ARMY RSRCH LABORATORY-HRED
ATTN AMSRD-ARL-HR-MK J REINHART
10125 KINGMAN RD
FT BELVOIR VA 22060-5828

ARMY RSRCH LABORATORY-HRED
ATTN AMSRD-ARL-HR-M M STRUB
6359 WALKER LANE SUITE 100
ALEXANDRIA VA 22310

ARMY RSRCH LABORATORY-HRED
ATTN AMSRD-ARL-HR-MN R SPENCER
DCSFDI HF
HQ USASOC BLDG E2929
FT BRAGG NC 28310-5000

ARMY RSRCH LABORATORY-HRED
ATTN AMSRD-ARL-HR-MW E REDDEN
BLDG 4 RM 332
FT BENNING GA 31905-5400

ARMY RSRCH LABORATORY-HRED
ATTN AMSRD-ARL-HR-MT J CHEN
12423 RESEARCH PARKWAY
ORLANDO FL 32826-3276

ARMY RSRCH LABORATORY-HRED
ATTN AMSRD-ARL-HR-MD T COOK
BLDG 5400 RM C242
REDSTONE ARSENAL AL 35898-7290

ARMY RSRCH LABORATORY-HRED
ATTN AMSRD-ARL-HR-MH C BURNS
BLDG 1467B RM 336 THIRD AVE
FT KNOX KY 40121

ARMY RSRCH LABORATORY-HRED
ATTN AMSRD-ARL-HR-MP D UNGVARSKY
BATTLE CMD BATTLE LAB
415 SHERMAN AVE UNIT 3
FT LEAVENWORTH KS 66027-2326

ARMY RSRCH LABORATORY-HRED
ATTN AMSRD-ARL-HR-MV HQ USAOTC
S MIDDLEBROOKS
91012 STATION AVE RM 111
FT HOOD TX 76544-5073

ARMY RSRCH LABORATORY-HRED
ATTN AMSRD-ARL-HR-MY M BARNES
2520 HEALY AVE STE 1172 BLDG 51005
FT HUACHUCA AZ 85613-7069

ARMY RSCH LABORATORY - HRED
AVNC FIELD ELEMENT
ATTN AMSRD-ARL-HR-MJ D DURBIN
BLDG 4506 (DCD) RM 107
FT RUCKER AL 36362-5000

US ARMY TRADOC
BATTLE LAB INTEGRATION & TECHL DIRCTRT
ATTN ATCD-B
10 WHISTLER LANE
FT MONROE VA 23651-5850

COMMANDANT USAADASCH
ATTN AMSRD-ARL-HR-ME A MARES (5 COPIES)
ATTN ATSA-CD
5800 CARTER RD
FT BLISS TX 79916-3802

DIRECTOR
DIRECTORATE OF COMBAT DEVELOPMENTS
ATTN COL H L COHEN
5800 CARTER RD
FT BLISS TX 79916-7001

DIRECTOR
DIRECTORATE OF TRAINING, DOCTRINE, & LEADER DEVELOPMENT
ATTN COL R K CARL
2 SHERIDAN RD, BLDG 2
FT BLISS TX 79916-7001

OFFICE, CHIEF OF AIR DEFNS ARTILLERY
ATTN LTC J H JENKINS III
2 SHERIDAN RD BLDG 2
FT BLISS TX 79916-7001

PM TIMS, PROFILER (MMS-P) AN/TMQ-52
ATTN B GRIFFIES
BUILDING 563
FT MONMOUTH NJ 07703

SMC/GPA
2420 VELA WAY STE 1866
EL SEGUNDO CA 90245-4659

TRADOC CAPABILITY MANAGER-LOWER TIER
ATTN COL R L DELGADO
BLDG 12, PERSHING RD
FT BLISS TX 79916-7001

COMMANDING GENERAL
US ARMY AIR DEFNS ARTILLERY CTR AND FT BLISS
ATTN MG R P LENNOX
BLDG 2 SHERIDAN RD
FT BLISS TX 79916-7001

US ARMY INFO SYS ENGRG CMND
ATTN AMSEL-IE-TD F JENIA
FT HUACHUCA AZ 85613-5300

COMMANDER
US ARMY RDECOM
ATTN AMSRD-AMR W C MCCORKLE
5400 FOWLER RD
REDSTONE ARSENAL AL 35898-5000

US ARMY RSCH LABORATORY
ATTN AMSRD-ARL-CI-OK-TP S FOPPIANO
BLDG 459
ABERDEEN PROVING GROUND MD 21005

US ARMY RSRCH LAB
ATTN AMSRD-ARL-CI-OK-TP TECHL LIB T LANDFRIED
BLDG 4600
ABERDEEN PROVING GROUND MD 21005-5066

US GOVERNMENT PRINT OFF
DEPOSITORY RECEIVING SECTION
ATTN MAIL STOP IDAD J TATE
732 NORTH CAPITOL ST., NW
WASHINGTON DC 20402

US ARMY RSRCH LAB
ATTN AMSRD-ARL-HR-S L PIERCE
ATTN AMSRD-ARL-HR-SE D HEADLEY
ATTN AMSRD-ARL-HR-SE K COSENZO
BLDG 459
ABERDEEN PROVING GROUND MD 21005

US ARMY RSRCH LAB
ATTN AMSRL-ARL-HR F PARAGALLO
BLDG 459
ABERDEEN PROVING GROUND MD 21005-5066

DIRECTOR
US ARMY RSRCH LAB
ATTN AMSRD-ARL-RO-EV W D BACH
PO BOX 12211
RESEARCH TRIANGLE PARK NC 27709

US ARMY RSRCH LAB
ATTN AMSRD-ARL-CI-OK-T TECHL PUB (2 COPIES)
ATTN AMSRD-ARL-CI-OK-TL TECHL LIB (2 COPIES)
ATTN AMSRD-ARL-D J M MILLER
ATTN IMNE-ALC-IMS MAIL & RECORDS MGMT
ADELPHI MD 20783-1197